DIAGNOSIS OF ATMOSPHERIC ENVIRONMENT FAVOURABLE FOR DEEP MOIST CONVECTION BY USING SATELLITE IMAGERY

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I. INTRODUCTION

The instability and low-level conditions are critical for the potential of a pre-convective environment to produce deep moist convection. In addition, a large majority of severe convective weather at mid-latitudes is associated with synoptic disturbances and experience shows that high impact convective events occur generally in areas where upper level synoptic forcing is acting in addition to a conditional instability of the atmosphere.

The paper is focused on the use of Meteosat Second Generation (MSG) data for diagnosis of potential influences on the initiation and intensity of deep moist convection that may help in analysis and early forecast of its development.

II. LOW- AND UPPER-LEVEL FEATURES OF A CONVECTIVE ENVIRONMENT SEEN BY SATELLITE IMAGERY

Conditions for low-level convergence as a forcing mechanism of convection outbreak can be diagnosed by MSG images channels IR 10.8 µm and IR 8.7 µm along lines of discontinuity in moisture, orography, temperature (FIG. 1a).

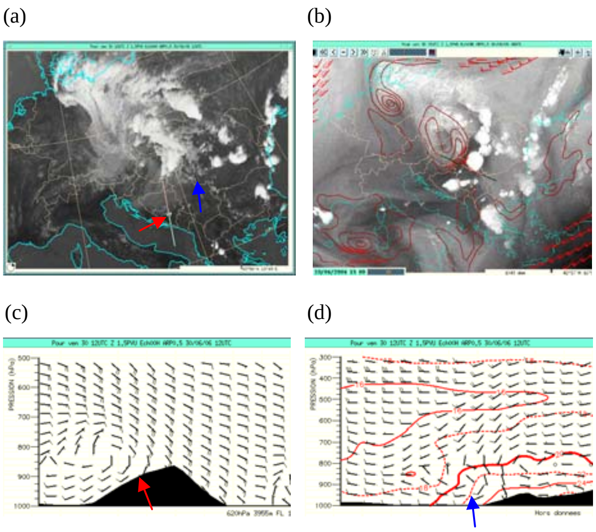

FIG. 1: MSG images 30/06/2006 in (a) 10.8 µm 12 UTC and (b) 6.2 µm 15 UTC, superimposed by NWP 1.5 PV-units heights (< 1000 dam) and 300 hPa wind (> 40 kt). Vertical cross-section of tangential wind component: (c) 12 UTC along the line in (a); (d) 15 UTC along the line in (b), red contours: wet-bulb potential temperature. The red/blue arrows indicate low-level convergence at 12/15 UTC.

The differential solar heating between the cloudy and cloud-free area (at the blue arrows in FIG. 1a) produces wind blowing from the cool to the warm side at the temperature gradient zone and a local circulation. The result is a low-level convergence at the line of discontinuity in moisture, orography and temperature. This is illustrated by the cross-section of the NWP derived tangential wind component in FIG. 1c.

In addition, the surface low-level moisture discontinuity is capped by upper-level favourable conditions (FIG. 1b). An advancing potential vorticity (PV) anomaly, seen as a dynamic dark zone on the WV image 6.2 µm, associated with a jet, produces upper-level forcing, which is capable to release the potential instability that is conductive for strong updraft in a deep tropospheric layer. FIGs. 1(b) and 1d) shows that the most intense convective cells develop downstream the PV anomaly at a zone of wet-bulb potential temperature gradient and convergence at the surface.

A convective environment is created near moisture boundaries in WV images 6.2 µm (Roberts, 2000; Krennert & Zwatz-Meise, 2003; Ghosh et al., 2008). Georgiev & Kozinarova (2009) stressed on the need, in addition to such a pure WV image interpretation, the upper-level dry boundaries to be considered with respect to the dynamic rate at which they are maintained.

FIG. 2a shows a WV image with dynamic moisture boundary, associated with a northeasterly upper-level jet in strong blocking regime. Upper-level forcing for vertical motion occurs due to the ageostrophic wind producing divergence at the left jet exit. The positive PV advection, associated with the jet is running in the blocking circulation from the northern Europe through the central and Eastern Mediterranean and then to the Black Sea that is associated with elongated dark strip of dry air in the WV images.

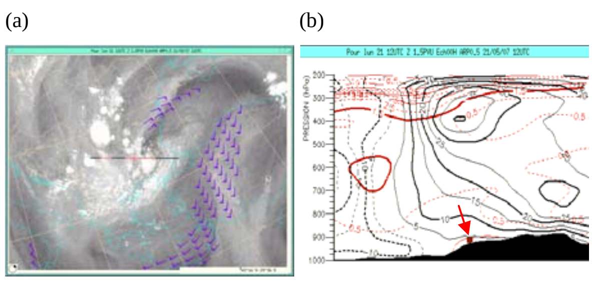

FIG. 2: (a) MSG image 17/05/2007 12 UTC, 6.2 µm channel, superimposed by NWP 1.5 PVU wind (> 46 kt). (b) vertical cross-section along the line in (a): PV (brown) and wind speed (black) perpendicular to the cross section. Tornado is going to occur at the red arrow in (b).

Many features of the surface chart for 1200 UTC on 17/05/2007 (not presented) show low-level conditions favourable for strong convective development as follows: A shallow surface depression; Moisture supply at low-level as a result of easterly surface winds from the Black sea at the western as well as southerly winds from the Mediterranean sea at the southern part of Bulgaria; The surface winds show a distinct convergence line over southern part of Bulgaria. As a result of coupling between low- and upper-level favourable conditions, a tornado occurred at the village Kelekovetz (42°14’ N 24°49’ E) in the southern part of Bulgaria on 21 May 2007 at about 1230 UTC just below the PV anomaly and the jet, as seen in FIG. 2b. A convective environment associated with PV anomaly advection from the north-east is not frequently created, however this kind of situation can produce severe weather events. Water vapour imagery offers the possibility to follow such kind of small PV anomaly features advected from north-east that is crucial in helping to diagnose upper-level forcing for convection in a blocking circulation, which enables the mechanisms to act over the same area for a long time.

III. DIAGNOSIS OF CONVECTIVE ENVIRONMENT BY WV IMAGERY: JET STREAM ANALYSIS PESPECTIVE

As shown in Section II the upper-level dynamics at the left-exit region of a jet is conductive for convection. A low-level baroclinic zone, associated with warm (and often moist) air from the surface to lower middle troposphere can be another important ingredient of convective environment that often produces a mid-level jet, visible in 7.3 μm WV images (Georgiev & Santurette, 2009).

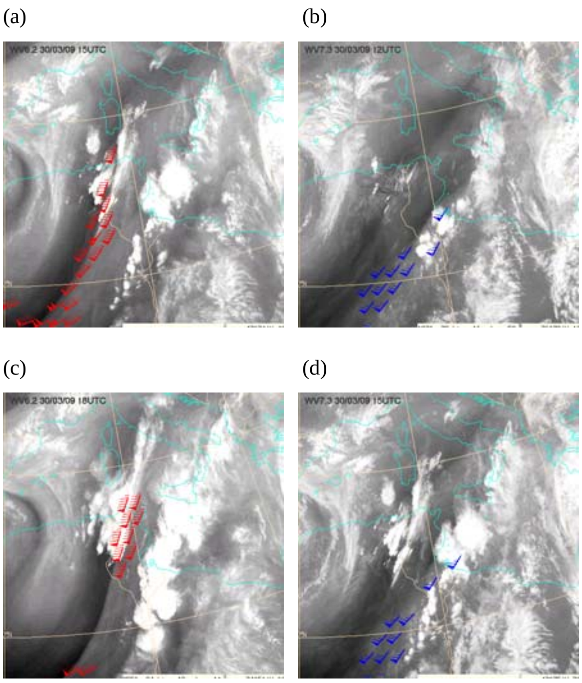

FIG. 3: MSG images 30/03/2009, overlaid by NWP wind: 6.2 μm, wind > 90 kt (a) 15 UTC and (c) 18 UTC; 7.3 μm wind > 60 kt (b) 12 UTC and (b) 15 UTC.

Therefore, MSG water vapour images can be used as observation data for jet stream analysis that usually enables to diagnose the pre-convective environment. FIG. 3 reveals the approach, which could be easily applied.

Imagery in WV channel 6.2 μm is a tool for upper-level jet-stream analysis, which enables diagnosing of upper-level forcing in a pre-convective environment: Convection is most likely to develop downstream left of an upper-level moisture boundary on the 6.2 μm images (FIGs. 1a and 1c).

Imagery in WV channel 7.3 μm is a tool for mid-level jet-stream analysis, which enables diagnosing low-level forcing in a pre-convective environment: Convection is most likely to develop downstream right of a mid-level moisture boundary on the 7.3 μm images (FIGs. 1b and 1d).

IV. SUMMARY: POTENTIAL INFLUENCES ON THE INTENSITY OF CONVECTION SEEN BY SATELLITE IMAGERY

MSG Imagery in IR and WV channels can be useful in analysis of various potential influences on the intensity of convection. Low-level convergence as a forcing mechanism of convection outbreak could be seen as a line of discontinuity of cloudiness and temperature in IR 10.8 μm and WV 8.7 μm images. A low-level baroclinic zone related to mid-level jet stream can be visible in WV 7.3 μm imagery. Convective instability due to buoyancy force of cold/dry air over warm/moist air is well seen by analysing both WV 7.3 μm and WV 6.2 μm images. PV anomaly advection, which is an important upper-level forcing mechanism, capable to release the potential instability and to favour strong updraft in a deep tropospheric layer, can be well detected in WV 6.2 μm imagery.

Images of difference between brightness temperatures in WV channels 6.2 μm and 7.3 μm can be used for inspection of potential instability moisture evolution at mid- and upper-levels that is controlled by advection and vertical motion. A new method for using such WVBTdif images in combination with relevant meteorological fields for analysis and nowcasting of deep moist convection is under development through the collaboration of Météo-France and NIMH of Bulgaria (Santurette et al., 2009).

In the frame of this research program, the Divergence Product – MSG is also under evaluation. Some case studies in May 2009 show convection developments occurring over the Balkans correlated with upper-level divergence (calculated at EUMETSAT from the field of the MSG channel 6.2 μm Atmospheric Motion Vectors).

IV. REFERENCES

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